start-up. For additional detail procedures refer to Appendix B: Express Lanes Operational Procedures (ELOP).

TOLL AMOUNT ADJUSMENT LOGIC

The operational goal of the I-95 Express Lanes is to provide free flow conditions along the facility. Under free flow conditions, vehicles are generally unimpeded and typically able to safely operate at speeds of 45 miles per hour or greater along an uninterrupted expressway segment. Real time responsive toll pricing is utilized to control traffic volumes in the EL and try to maintain free flow conditions.

The condition of traffic flow is defined by the *Highway Capacity Manual* (HCM) using an operational level of service (LOS). The LOS of a freeway facility is measured by traffic density (TD), which is a combination of speed and volume. TD is calculated as follows:

$$Traffic\ Density\ (vehicles\ per\ mile\ per\ lane) = \frac{Volume\ (vehicles\ per\ hour\ per\ lane)}{Speed\ (miles\ per\ hour)}$$

Figure 6.7.3-1 depicts the relationship between LOS and TD, which is derived from the HCM. LOS A, B and C are considered to be free-flow conditions and should safely allow for maximum throughput in the EL. As traffic conditions enter a LOS D and E, traffic conditions will begin to deteriorate, densities will begin to approach 45 vehicles per mile per lane (vpmpl) and travel speed will be reduced. For LOS F, densities are expected to be above 45 vpmpl and speeds are significantly reduced.

Level of Service	Traffic Density (vpmpl)	Expected Traffic Conditions
A	0 - 11	Free-Flow
B	> 11 - 18	Free-Flow
C	> 18 - 26	Free-Flow
D	> 26 - 35	Mild Congestion
E	> 35 - 45	Moderate Congestion
F	> 45	Severe Congestion

Figure 6.7.3-1: Level of Service and Traffic Density Relationship

The real time responsive toll amount adjustment logic utilizes concepts proven to be successful by other HOT facilities. The logic begins with an initial

operating toll amount schedule and compares the initial toll amount to a calculated toll amount based on current traffic conditions. Current traffic conditions are determined by real time traffic data collected from EL detectors. The data collected is processed to exclude erroneous data and averaged before a TD is calculated. The TD is used to determine the toll amount needed to optimize traffic flow.

The TD calculations are averaged for each EL segment every 15 minutes to respond to current traffic conditions. The TD calculation is then rounded to a whole number.

The toll amount calculations use configurable settings. The two primary settings are LOS settings and Delta TD (change in TD) settings. The LOS settings relate the current EL LOS with a TD range and a maximum and minimum toll amount range, as shown in Figure 6.7.3-2.

	Density		Rates	
LOS	**Minimum**	**Maximum**	**Minimum**	**Maximum**
A	0	11	$0.50	$0.50
B	12	18	$0.50	$1.50
C	19	26	$1.50	$4.25
D	27	35	$4.00	$10.50
E	36	45	$8.50	$10.50
F	>45		$9.50	$10.50

Figure 6.7.3-2: Level of Service Settings Table

The Delta settings relate a change in TD (ΔTD) with a change in toll amount (ΔR). Sample Delta settings are included in Figure 6.7.3-4.

The steps for calculating the current toll amount are presented in Figure 6.7.3-3. The TD calculated for the previous time period is subtracted from the TD for the current time period to determine the change in TD (ΔTD). Using the delta settings table (APPENDIX L), a rate change is determined. The toll amount change is added or subtracted to the previous toll amount to determine the current toll amount. The current toll amount is compared to the maximum and minimum toll amounts in the LOS settings table (Figure 6.7.3-2). If the current toll amount falls outside the maximum or minimum toll amounts for the corresponding TD, then the maximum or minimum toll amounts are applied, respectively. If the current toll amount falls within the maximum or minimum toll amounts, then the current toll amount is applied. For example, the previous

toll amount is \$1.50 and the previous TD is 20. The current TD is 23. The current toll amount is calculated as follows:

$\Delta TD = TD_t - TD_{t-1} = 23 - 20 = 3$
$R_t = R_{t-1} + \Delta R = \$1.50 + \$0.50 = \$2.00$ *(from Table 6.7.3-4, a TD of 23 and a change in TD +3 yields a +\$0.50)*

The current toll amount falls within the toll amount ranges for a Level of Service C (TD=23). Therefore, a toll amount of \$2.00 is used.

Step 1: Calculate ΔTD

$$\Delta TD = TD_t - TD_{t-1}$$

Step 2: Find ΔR based on ΔTD and TD_t

*Refer to Delta Settings Matrix (see **Table 6.7.3-4**)*

Step 3: Calculate R_t

$$R_t = R_{t-1} + \Delta R$$

Step 4: Decide Final R_t

$$R_t = \begin{cases} Max, \text{ if } R_t > Max \\ Min, \text{ if } R_t < Min \\ R_t, \text{ otherwise} \end{cases}$$

Where:

R_t – Current Toll Amount
R_{t-1} – Previous Toll Amount
TD_t – Current Traffic Density
TD_{t-1} – Previous Traffic Density
ΔTD – Change in Traffic Density
ΔR – Toll Amount Adjustment
Max – Maximum Toll Amount at a LOS
Min – Minimum Toll Amount at a LOS

Figure 6.7.3-3: Current Toll Amount Calculation

Performance Factor (Transparent to Operators)

Performance Factor (PF) is an adjusting factor that is utilized to increase Traffic Density (TD) when EL performance degrades. By increasing TD intentionally, toll amounts can be increased more effectively and thus maintain acceptable performance of EL. Note: During times when Express Lanes are encountering performance problems, this factor will allow or force the rate to increase faster than under normal operations.

It is calculated by the percent of individual detectors (DS in the formula) below X MPH, which is a configurable number associated with a configured EL segment in ELM. For each time interval analyzed, the number of detectors below X MPH is converted to a percentage. That percentage is applied to the traffic density (TD) to calculate a new traffic density (TD_n), which is then used to calculate the new toll amount, see below:

$$\mathrm{PF} = \frac{\#\ \mathrm{of\ DS} < X\ \mathrm{MPH}}{\#\ \mathrm{of\ DS}}$$

$$TD_n = TD + TD * PF$$

The configurable threshold X will be recommended by the engineer and configured by the analyst however operation staff will not be required to change it. From an operations point of view, one should witness toll rate increases more rapidly when EL speed drops below X mph.

Modified Re-Open Procedure (Sharing with Operators)

The EL recovery procedure from closure was modified to address race condition. The proposed modification will reduce the risk of toll amounts decreasing by allowing a normal rate (or time-of-day rate) check at the first calculation interval before dynamic tolling is fully restored. Meaning when the EL come out of closed and a schedule update is going to occur, this procedure will minimize the risk of implementing a low rate so the EL may see a higher rate than normal when dynamic mode is first implemented.

The Figure 6.7.3-4, Toll Calculation during EL Recovery from Closure, below demonstrates how the new procedure works. In the figure: once the EL is reopened, immediate effect toll amount (Ri) will be either the Time of Day toll amount (Rn) or the last calculated toll amount (R0), whichever is greater, and TDi is either TD0 or TDn according to which toll amount is chosen. When a

proposed scheduled interval of toll calculation starts, the toll amount for the first interval (R1) is calculated using current TD1, TDi and Ri, then this R1 is compared with Ri, Ri will replace R1 if R1 < Ri. Dynamic tolling is recovered in the second scheduled interval.

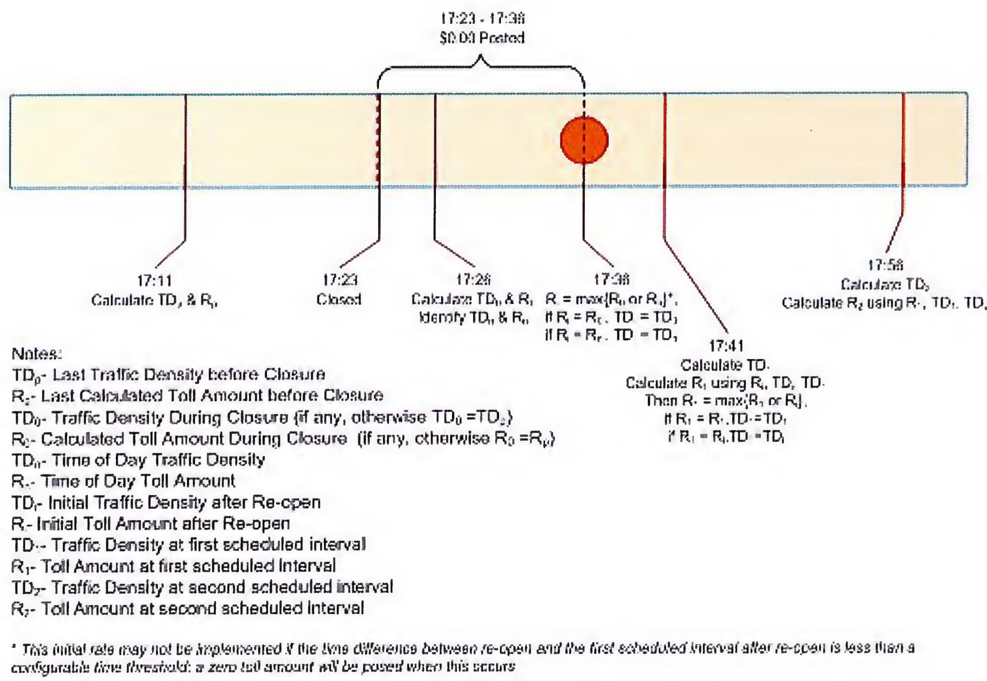

Figure 6.7.3-4: Toll Calculation during EL Recovery from Closure